
6. CONCEPTUAL SITE MODELS

Introduction

The four Principles of environmental restoration presented in chapters 1 – 5 provide a philosophy and framework for conducting site investigations, remedial design and implementation and, when necessary, long-term care of sites. Chapters 6 – 9 present tools and methodologies for conducting site work that embrace and embellish upon the Principles.

A conceptual site model (CSM) is a depiction of key elements and interfaces that describes the fate and transport of contaminants from source to receptor at a given AOC. It is a means of organizing data, identifying decisions to be made, identifying significant uncertainties, and communicating the overall understanding of the site amongst the PMT and technical support as well externally to stakeholders. It facilitates development of the problem statement, and to the extent that viable responses must control sources, interrupt pathways, or isolate receptors, it assists in identifying the hierarchy of preferred technologies. Finally, it serves to identify data needs and provides a means of determining their significance relative to whether a problem exists.

This chapter describes the uses of the CSM and provides guidance on form and content that maximize its utility as a means of communicating with stakeholders. The linkage between the CSM and the problem statement are explored with particular emphasis on considerations relative to future site use.

The CSM as a Management Tool

Any model is a cartoon or abstract of reality. It is intended to convey relationships and interfaces between component parts in a form that enhances one's ability to understand those interrelationships and use them in a diagnostic and/or predictive mode. There are many formats for models depending on the intended use and the complexity of data available to put in them. A CSM can be a simple drawing or diagram, a narrative description, or a sophisticated numerical construct depicting the spatial relationship of key elements that determine the fate and transport of contaminants such as location of source materials, the direction of transport, presence and nature of media affecting transport, and extent of contamination.

Initially, a CSM is used to organize information on how contaminants have potentially been released and transported. Ultimately, it helps to conduct evaluations of complete chemical transport pathways and focus on appropriate response actions. For a potential risk to be associated with a release, there must be a complete pathway from the source to a receptor and the receptor must be there when the contamination arrives or is still present. As a consequence, risk-

based concerns only exist when transport by complete pathways is sufficient to exceed acceptable risk levels in the time frame in which exposure, human or ecological, will occur. The data needed to characterize chemical transport pathways are identified (to an appropriate degree) through use of the CSM. The presence of receptors and the degree of exposure are most often determined by the likely land/resource use patterns present at the time of arrival (based on EPA directives on land use determinations).

For maximum benefit, the PMT can use the CSM to assist in identifying critical decisions, and then communicating those decisions effectively. This is contrasted with a common approach wherein the CSM is simply a product of the remedial investigation. The PMT can also use the CSM to show how the understanding of site conditions changes as additional data are collected, or to illustrate why data collection activities are not needed to proceed. As such, there are three key concepts regarding CSMs:

1. The CSM is used to organize and communicate information about site characteristics.

The CSM should reflect the best interpretation of available information at any point in time (i.e., the model should be considered a reflection of current understanding rather than a single point in time). If new data are found to be inconsistent with the model, either the data are in error, or the model needs to be revised. Similarly, any hypothesis posed for the site and any remedy evaluated must be consistent with the CSM. Evaluating a remedy that relies on mechanisms inconsistent with the CSM is wasted effort. The CSM represents the location and the interrelationships of site features that affect fate and transport of contaminants from source to receptor. As such, it can be used as a tool to determine if all current or potential future receptor exposures associated with a contaminant release have been identified. Moreover, since responses can remove sources, intercept pathways, or isolate receptors, the CSM can help to identify and evaluate candidate responses.

2. The CSM helps identify data needs.

To the extent that the CSM reflects the best understanding of the site, uncertainties (data gaps) become clearly visible. Moreover, since pathways must be complete before a receptor is exposed to source chemicals, the CSM can also indicate when an uncertainty is not significant (e.g., relates to an incomplete pathway).

3. The CSM is a primary vehicle for communicating complete chemical transport and exposure pathways.

It provides a good summary of how and where contaminants are expected to move and what impacts such movement may have. Hence, it supplies additional

information to explain why a problem is a problem, why it is inconsistent with desired results and, therefore, why a response is anticipated. By highlighting complete pathways, the CSM facilitates identification and communication of environmental concerns. Ultimately, the data needed are those that assist in making the important identified decisions in a consistent manner. One way to identify the right decisions and, therefore, collect the right data is to have a complete and accurate CSM.

CSM Form and Content

While there are many different forms of a CSM that the PMT may elect, a good CSM accomplishes the following five objectives:

- Identifies and locates contaminants, sources, release and transport mechanisms, transport pathways, intake routes, and receptors;
- Delineates contaminant, concentrations in media, and flux rates by pathway in narrative and graphical forms;
- Quantifies background concentrations for each formation or unit;
- Explicitly recognizes and highlights uncertainties (known and unknown conditions); and
- Evolves with data and other information (new site-use history information).

A CSM benefits from use of multiple formats to best portray available information. A good narrative summary is the best means of describing the AOC, its history, the nature of sources, quantitative aspects of migration pathways, and the identity of ecological and human receptors as well as the circumstances under which exposure is anticipated. Examples of such narratives are included in Appendix D and materials available from the American Society for Testing and Materials (ASTM) [Reference numbers PS85-96, E1689-95, <http://www.astm.org>]. As with the initial CSM, the narrative should be simple and concise. When data are presented, they should be synoptic, but representative of key findings relative to the problem statement and potential risks. The CSM will be a major part of any communications with stakeholders and, therefore, should be written without a lot of technical jargon or misleading information. Major components include:

- AOC summary;
- AOC description;
- Source description;
- Pathway descriptions; and
- Receptor identifications and descriptions.

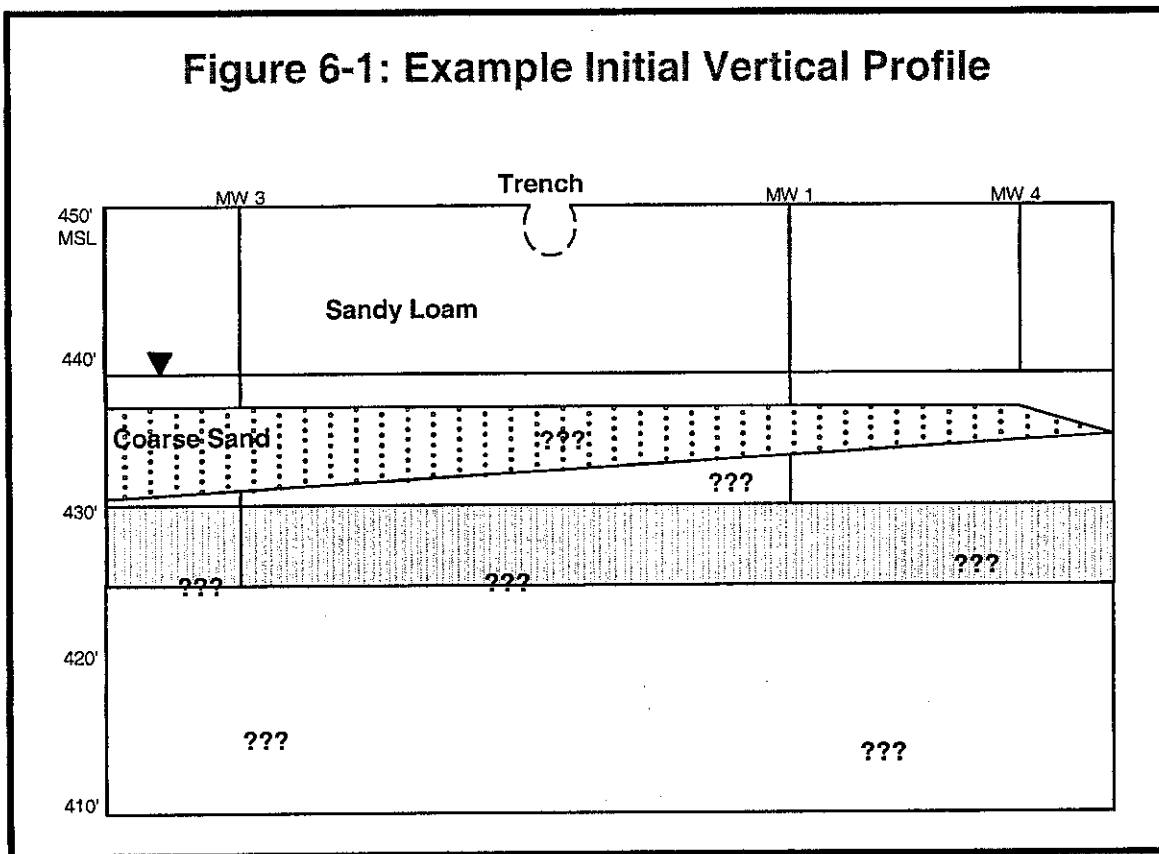
Maps should always be included in a CSM. At a minimum, maps should include relative position of sources, pathway determinants and near-field boundary constraints, surface water features, prevailing wind pattern, and plume contours. When multiple contaminants are present, it may be necessary to produce separate maps of each contaminant group to keep from obscuring data through multiple overlays. If subsurface contamination is present, a vertical profile of the site should be included. Fence diagrams or representative boring logs may suffice, but simplified forms focused on the most important features are best in order to facilitate communication with stakeholders. Tabular data may be included, but tables should be keyed to map features and should contain representative data only, not an exhaustive display of all data.

A standardized summary wire diagram format has been developed for use in EPA documents. These depictions show at a glance the identity of completed pathways, including their source, release mechanisms, transport mechanisms, intake routes and receptors. The stylized graphic is a handy summary, but not a substitute for the entire CSM package. Quantitative aspects, spatial relations, and unique features that impact on the true nature of resultant exposure are not to be found in the wire diagram. Moreover, it serves more to summarize the findings of investigations than to focus remaining activities.

One means of producing flow diagrams is the application of the Site Conceptual Exposure Model (SCEM) Builder. An advantage of using this software is that it can easily evaluate several alternative CSMs and can be used to quickly evaluate whether an agreement can be reached on a CSM produced by a technical support contractor. The SCEM Builder is available (at no cost) at <http://www.eh.doe.gov/oepa>. When you pull up the web site, click on "Tools," then "Site Conceptual Exposure Model (SCEM) Builder," and follow the directions for downloading.

Initially, the CSM is used both to organize the discussion of available data and to identify data needs. In the mapped form, uncertainties can be highlighted by question marks (see Figure 6-1). In the narrative form, unknowns should be specifically called out and critical data needs identified where appropriate. Whenever groundwater pathways are involved, a vertical profile should be included to help interpret data and visualize potential pathways. All pathways should be discussed including those not judged complete. In that way, the CSM serves as a checklist indicating that all pathways have been considered and why specific pathways have been excluded.

Figure 6-1: Example Initial Vertical Profile



To identify releases and distinguish those originating from site activities as opposed to off-site sources, it may be important to establish background concentrations. Background may arise from naturally occurring substances (minerals, plant residues), deposition from regional or global transport (fallout), or plumes from up-gradient sources. Because geochemistry can change with the nature of the host geology, background levels may be different for different soil types and aquifer units. Guidance on establishing background concentrations and using them to identify site-related releases is available from sources such as the California Department of Toxic Substances (*Selecting Inorganic Constituents as Chemicals of Potential Concern for Risk Assessments at Hazardous Waste Sites and Permitted Facilities, February 1997*, downloadable at <http://www.dtsc.ca.gov/sppt/opptd/pollprvn/p2sb14gm.pdf>).

With data collection, some of the uncertainties at an AOC are likely to be reduced or removed. That reduction should be reflected in the CSM. The PMT can revise the CSM by removing question marks and replacing statements about uncertainty with descriptions of sources, pathways, and receptors. This ensures that the CSM accurately reflects the current understanding of site conditions and remaining uncertainties.

The CSM should contain only features and data that are important to the risk manager. As such, the focus is on the problem statement as currently written and the viable pathways for which unacceptable risk has been identified. Hence, the problem statement and CSM should always be consistent and evolve with new data as acquired.

Land Use and the CSM

As is apparent from guidelines for risk assessment, the nature of land and resource use dictates the identity of the receptor populations, exposure or intake route, and the circumstances under which the exposure will occur. Exposure scenarios differ significantly with land use. While current use is easily identified, future use is always an uncertainty that must be dealt with for persistent contaminants. A simple approach to managing this uncertainty has been to constrain future use through institutional controls. Such responses must be made compatible with prevailing land use policies. In a recent review of risk-based decision making, the National Research Council noted that the common deferral to containment remedies with risk-based decision making increases the need for realistic and comprehensive evaluation of long-term use potential.

Current and *reasonably anticipated* future land uses and corresponding exposure scenarios should be considered in the selection and timing of corrective actions. If land use changes can be predicted, they can serve as a basis for phased responses. As the uncertainty with respect to future use increases, there are more incentives to select robust remedies and well-defined contingencies. Reasonable land use assumptions should be assessed when developing goals for any given facility and used to focus all aspects of the remediation process. When major structural changes are anticipated (e.g., changes in industrial base, closure of large activities, resource depletion), the uncertainty can be bounded or the reasonable alternatives expanded. In any event, change is inevitable and should be managed as an uncertainty. It is not sufficient to assume current use will remain indefinitely or that zoning restrictions will withstand economic pressures in the future if there are no compelling reasons to corroborate that assumption (e.g., presence of wetlands that would preclude development of residences). However, it is also not fiscally responsible to assume that the least restrictive land use (i.e., residential), if in fact there are factors that suggest that residential use is not a reasonable alternative in the future.

The CSM and Data Collection

The thought process applied to focus data collection efforts draws on the CSM to answer questions at the core of each fundamental decision and from which priorities are established. Once enough information is available to write a problem statement, a problem exists. Therefore, by definition it requires a response to solve the problem. At this point, attention needs to shift from the first

question - Does a problem exist? - to the second question - What and when will something be done to address it?

Further data collection relative to nature and extent of contamination is important only to the degree that nature and extent may change the acceptability of the risk and the approach to remediation (Figure 6-2). This does not mean data needs no longer exist. It means that the data needed are those associated with evaluating and selecting the response. If data will not change the decision being made, they are not necessary for selection or completion of a response. For example, if groundwater data confirm the presence of contamination posing unacceptable risk within a defined plume boundary, further sampling within that boundary will not change the decision that a problem exists. Therefore, additional testing must be justified on the basis of how results can alter the selection or design of a remedy.

Recognizing that the focus is now on responses, the PMT's efforts will be most productive if they can identify a limited number or a single response that is most likely to result in an acceptable risk. For many installations, narrowing the list of candidate technologies is readily accomplished using past history as discussed under the third Principle.

Figure 6-2: Data Collection Decision Logic for Risk-Based Problems

